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A Coupled Ocean-Atmosphere Radiative Model for Global Ocean Biogeochemical Models

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Abstract. An ocean-atmosphere radiative model (OARM) evaluates irradiance availability and quality in the water column to support phytoplankton growth and drive ocean thermodynamics. An atmospheric component incorporates spectral and directional effects of clear and cloudy skies as a function of atmospheric optical constituents, and spectral reflectance across the air-sea interface. An oceanic component evaluates the propagation of spectral and directional irradiance through the water column as a function of water, five phytoplankton groups, and chromophoric dissolved organic matter. It tracks the direct and diffuse streams from the atmospheric component, and a third stream, upwelling diffuse irradiance. The atmospheric component of OARM was compared to data sources at the ocean surface with a coefficient of determination (r^2) of 0.97 and a root mean square of 12.1%.

1 Introduction

Knowledge of oceanic irradiance is critical for realistic simulation of ocean biogeochemistry. Since irradiance affects ocean thermodynamics and physiological processes of biota in the oceans, it may affect the abundances and distributions of phytoplankton, and potentially affect the uptake of carbon dioxide.

In order to understand the effects of irradiance on phytoplankton abundances and primary production in the global oceans, we require a reasonably realistic simulation of the irradiance reaching the ocean surface, and propagating through the water column. The simulation must explicitly include the effects of atmospheric optical constituents on surface irradiance, processes occurring at the air-sea interface, and the results of these effects in the water column taking into account the optical properties of the water, phytoplankton, and dissolved detrital materials. In this paper we describe atmospheric and oceanic radiative transfer models, combined as the Ocean-Atmosphere Radiative Model (OARM) that provide a reasonably complex and realistic representation of atmospheric radiative processes and the irradiance availability in the oceans.

2 Ocean-Atmosphere Radiative Model (OARM)

2.1 Atmospheric Component.

The atmospheric radiative model is based on the Gregg and Carder (1990) spectral model for clear skies, and relies on Slingo (1989) for spectral cloud transmittance. The clear sky model of Gregg and Carder (1990) was derived from Bird and Riordan (1986), but was limited to the spectral range of photosynthetically available radiation (PAR), defined as 350-700 nm. It also contained increased spectral resolution and marine atmospheric and surface reflectance conditions. It compared within $\pm$6.6% root mean square (RMS) with surface observations of spectral irradiance and $\pm$5.1% RMS with integrated PAR (Gregg and Carder, 1990). This model is extended for OARM from the PAR spectral domain to the entire solar spectrum, from 200 nm to 4 um, representing >99% of the total solar irradiance impinging on the top of the atmosphere. For computational efficiency, the spectral resolution is degraded from 1 nm used in Gregg and Carder (1990) to a variable resolution appropriate for the spectral absorbing properties of the major atmospheric optically active gases, specifically ozone, water vapor, oxygen, and carbon dioxide (Table 1). The spectral resolution is fixed at 25 nm for the PAR range, which is the region of interest for phytoplankton photosynthesis.